SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

DTIC FILE COPY

(2)

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

AD-A221 543

1b. RESTRICTIVE MARKINGS	
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	
3. DISTRIBUTION / AVAILABILITY OF REPORT	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	
5. MONITORING ORGANIZATION REPORT NUMBER(S)	AFOSR-TR- 90-0429
6a. NAME OF PERFORMING ORGANIZATION	University of Massachusetts Medical School
6b. OFFICE SYMBOL (If applicable)	
6c. ADDRESS (City, State, and ZIP Code)	55 Lake Ave. N. Worcester, MA 01655-2319
7a. NAME OF MONITORING ORGANIZATION	
7b. ADDRESS (City, State, and ZIP Code)	AFOSR/NL Bolling AFB, DC 20332
8a. NAME OF FUNDING / SPONSORING ORGANIZATION	AFOSR
8b. OFFICE SYMBOL (If applicable)	NL
8c. ADDRESS (City, State, and ZIP Code)	Bldg 410 Bolling AFB, DC 20332
9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER	AFOSR-89-0247

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO	WORK UNIT ACCESSION NO.
61102F	2313	A5	

11. TITLE (Include Security Classification)
Non-Linear Analysis of Visual Cortical Neurons - First Annual Report

12. PERSONAL AUTHOR(S)
Jacobson, Lowell D., Gaska, James P., Pollen, Daniel A.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Annual	FROM 890101 TO 891031	900312	

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Binocular vision, nonlinear system identification, neural network

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

During the first reporting period, new equipment was purchased and set up and new software was developed in preparation for electrophysiological experiments to study the neural networks that underly the binocular non-linear filtering properties of cells in the monkey (Macaca fascicularis) visual cortex. This preparatory task was completed. In addition, new methods were developed for using input-output measurements to identify multi-input nonlinear systems. These new mathematical results have been written up and accepted for journal publication and presented at two conferences. In addition, the new system identification methods have been applied in preliminary analyses of previously obtained monocular stimulus-response data.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT	21. ABSTRACT SECURITY CLASSIFICATION
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	

22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE (Include Area Code)	22c. OFFICE SYMBOL
John F Tangney	(202) 767-5021	NL

DD Form 1473, JUN 86 Previous editions are obsolete. SECURITY CLASSIFICATION OF THIS PAGE

90 05 10 118

UNCLASSIFIED

Report

AFOSR-TR- 90-0429

NON-LINEAR ANALYSIS OF VISUAL CORTICAL NEURONS - FIRST ANNUAL REPORT

Lowell D. Jacobson, James P. Gaska, and Daniel A. Pollen
Department of Neurology
University of Massachusetts Medical School
55 Lake Avenue North
Worcester, MA 01655

12 March 1990

Annual Report for Period 1 January 1989 - 31 October 1989

Prepared for

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH
Bowling Air Force Base
DC 20332

SUMMARY

During the first reporting period, new equipment was purchased and set up and new software was developed in preparation for electrophysiological experiments to study the neural networks that underlie the binocular non-linear filtering properties of cells in the monkey (Macaca fascicularis) visual cortex. This preparatory task was completed. In addition, new methods were developed for using input-output measurements to identify multi-input nonlinear systems. These new mathematical results have been written up and accepted for journal publication and presented at two conferences. In addition, the new system identification methods have been applied in preliminary analyses of previously obtained monocular stimulus-response data, the results of which were presented at the 1989 ARVO Conference, Sarasota FL, and the 1989 Neuroscience Conference, Pheonix, AZ.

RESEARCH OBJECTIVES

The objective of this project is to provide an enhanced understanding of the detailed binocular spatiotemporal circuits that underlie the photic responses of single neurons in visual cortical areas V1 and V2 of the monkey. To accomplish this goal, the investigators are developing and applying nonlinear system identification methods that are applicable to multi-input / single-output (MISO) networks. Using these methods, one first uses each neurons's measured input-output mapping to determine whether the actual MISO network that underlies the neuron's visual responses is consistent with various hypothesized network structures. The candidate structures are drawn from a large superclass of MISO networks that include cascade, parallel, and feedback configurations of (a) linear time invariant spatiotemporal filters, and (b) memoryless (static) nonlinearities. Once consistent network structures have been identified, one proceeds to estimate the parameters associated with each linear filter and static nonlinear subsystem. This completes the network identification process. The above methods enable one to test, and extend, current models for the binocular responses of so-called "simple cells" and "complex cells" in the primate visual cortex.

Data describing the structure and parametrization of the MISO network structure of each studied neuron will be summarized together with anatomical information about cell location relative to laminar and columnar landmarks. Together, these data will be statistically analyzed to produce a taxonomic and parametric description of the binocular visual circuits within different subsystems of V1 and V2. The results from these analyses will also be used to refine and extend a model previously developed by the investigators for the binocular visual filtering performed by neurons in the monkey cortex. The revised model will serve to encapsulate the new experimental knowledge gained in this

investigation.

Beyond improving our scientific understanding of binocular filtering in the monkey visual cortex, the results of this research should also find near-term application to human factors engineering as well as the engineering of advanced machine vision systems. Moreover, the new analytic methods developed for this project should find broad application to the study of both visual and non-visual networks in natural and artificial neural systems.

RESEARCH STATUS

During the first reporting period, new methods were developed for using input-output measurements to identify the nonlinear, multi-input networks that underlie the binocular responses of single neurons in the primate visual cortex. After first developing methods appropriate for multi-input feedforward cascade nonlinear systems, considerable progress was subsequently made in extending these methods to encompass an enlarged class of nonlinear systems that include multi-input additive- and shunting-feedback networks such as those frequently encountered in the neural net literature. Such feedback (or related feedforward) normalization circuits may, for example, be responsible for the adaptation of cortical neurons to visual stimulus contrast.

The results developed for feedforward systems have been accepted for publication in Biological Cybernetics, and reported at two conferences. In addition, the new results have been used to perform preliminary analyses of the ternary kernels associated with neurons that were studied in past experiments. These results were reported at the 1989 ARVO and Neuroscience meetings.

During the first (10 month) reporting period, much effort was devoted to upgrading laboratory facilities since the equipment that was previously used for visual stimulus presentation was not suitable for the proposed binocular studies. In particular, spatiotemporal Gaussian white noise (GWN) plays a critical role in the multi-input system identification methods used in this investigation. Prior even to submission of the original proposal for this project, it was necessary to estimate the minimum computational and graphical performance that is required to generate a binocular 2D Gaussian white noise stimulus of adequate resolution. As justified in the original proposal, it was determined that only a high performance workstation would have sufficient performance to generate the required stimulus. To fulfill this requirement, on February 9, 1989, a 4D/120 GTX "super" workstation was purchased from Silicon Graphics and subsequently received on March 27, 1989. The system configuration includes 8 MB of main memory, 700 MB of disk space, a 60 MB 1/4 inch cartridge tape backup unit, and a Genlock board with NTSC color outputs. Aside from neural spike data

acquisition, which is handled by a slave PC/AT, the Silicon Graphics workstation currently handles all other aspects of visual stimulation and control during the actual experiments. It also handles the high post-experiment data processing load which the analysis methods impose.

After receiving the equipment, all important pre-existing laboratory data and software was ported to the 4D/120 GTX, and several new application programs were developed in preparation for the new experiments. Early ports included (1) a program for N-ary white noise stimulus presentation that uses a Feedback Shift Register approach for random number generation, and (2) a program for presentation of traditional stimuli that are presented in a randomly interleaved fashion (drifting gratings, bars, etc.) Whereas the old IBM PC/AT based versions of these two applications directly acquired spikes via data acquisition hardware on the PC/AT data bus, the new Silicon Graphics versions required a more complex spike gathering approach since the 4D/120 GTX, as configured, has no hardware for data acquisition.

The solution to this problem was to continue to use the old IBM PC/AT and associated hardware for spike acquisition, but now as a slave device controlled by the 4D/120 GTX. Suitable software was therefore developed on the PC/AT to enable it to fulfill its new role. This involves synchronizing its operation with the 4D/120 GTX via state and toggle control inputs, acquiring spikes, recording their time of occurrence, and immediately communicating the acquired data in compressed form over a serial port connection to the 4D/120 GTX.

Complementary software was developed on the 4D/120 GTX to implement its control and communication roles. The communication task on the 4D/120 GTX is handled by a perpetually running daemon program that simply monitors its serial port input for packets of spike data from the PC/AT and deposits this data in a semaphored ring buffer in a shared memory segment on the 4D/120 GTX. The packets of spike data deposited in the semaphored ring buffer can then be immediately accessed and displayed by any stimulus presentation program via a standard software interface. The control task of the 4D/120 GTX is handled by standard routines, linked into each stimulus presentation program, which issue synchronization and control information to the PC/AT via digital output lines that are located on the 4D/120 GTX's genlock board.

The two stimulus presentation programs (ie., N-ary white noise and traditional stimuli) were greatly enhanced following their initial port to the 4D/120 GTX environment. In particular, the white noise stimulation program was enhanced by adding 2D Gaussian white noise stimuli to its repertoire and also by adding a greatly improved random number generator that uses a shuffled linear congruential algorithm. The ability to present Gaussian white noise is a crucial element of the current project since the

advanced methods being used to decompose nonlinear neural circuits are properly applied only when Gaussian white noise is used as a visual stimulus. The generation of 2D Gaussian white noise stimuli was well beyond the capabilities of the equipment previously used by the investigators. However, on par with initial expectations, the 4D/120 GTX, when pushed to its limits, does a good job of presenting 2D Gaussian white noise.

The task of integrating the new computer into the laboratory was completed during the first (10 month) reporting period. Subsequently, during the first month of the second reporting period, a series of successful experiments were begun that made use of the new equipment and software. The results from these experiments are presently being analyzed and will be described in a future progress report.

PUBLICATIONS

Jacobson, L.D., Gaska, J.P., Chen, H-W. and Pollen, D.A. (1989) 2D spatial / 1D temporal white noise stimulus-response cross-correlation studies in V1 of the macaque monkey. In Invest. Opthalmol. Visual Sci. (suppl.) 30, p 298.

Pollen, D.A., Gaska, J.P. and Jacobson, L.D. (1989) Physiological constraints on models of visual cortical function. In Models of Brain Function. Ed. Rodney M.J. Cotterill. Cambridge: Cambridge University Press, 115-135.

Chen, H-W., Jacobson, L.D. and Gaska, J.P. Structural classification of multi-input nonlinear systems. To appear in Biological Cybernetics.

Gaska, J.P., Jacobson, L.D., Chen, H-W. and Pollen, D.A. (1989) Structural modeling of nonlinear networks in V1 of the macaque monkey. In Society for Neuroscience Abstracts, 19th Annual Meeting, Phoenix, AZ, p 1056.

Chen, H-W., Jacobson, L.D., Gaska, J.P. and Pollen, D.A. (1989) Structural classification of multi-input biological nonlinear systems. In Proceedings of the IEEE International Conference on Systems, Man, and Cybernetics, Cambridge, MA, 903-908.

PROJECT PERSONNEL

Lowell D. Jacobson, Ph.D.	(100% effort, Principal Investigator)
James P. Gaska, Ph.D.	(40% effort, Co-Principal Investigator)
Daniel A. Pollen, M.D.	(20% effort)
Hai-Wen Chen, M.S.	(100% effort)

INTERACTIONS

The investigators presented results from this project at the 1989 ARVO Conference, Sarasota, FL (Poster), the 1989 Models of Brain Function Meeting, Copenhagen, Denmark (Oral Presentation), the 1989 Neuroscience Conference, Pheonix, AZ (Poster), and the 1989 IEEE International Conference on Systems, Man, and Cybernetics, Boston, MA (Oral Presentation).

The investigators met with Dr. M. Shetzen, Northeastern University, Boston (coauthor with Y.W. Lee on the famous paper that made the derivation of Wiener kernels routine) to discuss results described in the structural classification paper to appear in Biological Cybernetics. Based on mutual interest in the use of system kernels as a basis for structure and parameter identification, Dr. Shetzen and the investigators have agreed to collaborate on future papers.

The investigators sent ternary first-order cross-correlation functions from both "unoriented" and "simple" cells to R. Young at General Motors Corporation. He is working collaboratively to fit analytic functions to the estimated spatiotemporal impulse responses of cortical neurons. R. Young already has much experience fitting receptive field data from various laboratories, and has published a number of papers describing his results. Fortunately, R. Young has recently purchased a Silicon Graphics workstation, allowing both laboratories to use identical nonlinear regression packages to enhance their collaboration on the data analysis tasks.

NEW DISCOVERIES

During the first reporting period, new methods were developed for using input-output measurements to identify nonlinear, multi-input networks. After first developing methods appropriate for multi-input feedforward cascade nonlinear systems, considerable progress was subsequently made in extending these methods to encompass an enlarged class of nonlinear systems that include multi-input additive- and shunting-feedback networks such as those frequently encountered in the neural net literature.